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Development of a PBL E-module Integrated with Reog Ponorogo Ethnoscience to Improve Critical Thinking Skills

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Abstract

This research aims to develop a Problem-Based Learning (PBL) e-module integrated with ethnoscience of Reog Ponorogo to enhance critical thinking skills. This research falls under development research, utilizing the 4D model (define, design, development, disseminate). The e-module was validated by three experts: media experts, material experts, and language experts, with six validators in each category. Additionally, a limited trial was conducted through a readability test involving two science teachers and ten seventh-grade students. The results of this research are as follows: (1) The e-module integrates local culture elements of Reog Ponorogo as learning material and is analyzed scientifically; (2) The validity results using Aiken's formula indicate that all items were declared valid, as the calculated V value was greater than the V table (0.78) for 30 media validation items, 17 material validation items, and 9 language validation items; (3) The response results from the limited-scale readability test showed an average score of 90.5 from teachers and 87.3 from students, categorized as very good. Thus, the developed e-module has met the feasibility standards as a digital learning resource and can be tested on a larger scale to evaluate its effectiveness in improving students' critical thinking skills.

How to Cite

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INTRODUCTION

Science learning is a process aimed at developing a holistic understanding of scientific concepts through an inquiry-based and problem-solving approach (Jumanto & Widodo, 2018). The essence of science learning is not solely focused on the transfer of knowledge but also emphasizes the development of critical thinking skills, problem-solving abilities, and scientific attitudes that reflect the scientific method (Aisah, 2020). Effective science learning should be contextual, relevant to everyday life, and capable of fostering 21st-century skills such as scientific literacy, collaboration, and scientific communication (Sunarti, 2024).

The Merdeka Curriculum in Natural Sciences education is designed to provide flexibility for educators in developing more contextual, interactive, and student-centered learning experiences (Gumilar, 2023). This curriculum encourages the implementation of a scientific approach involving observation, experimentation, and data analysis, enabling students to develop stronger critical thinking skills (Al Fajri & Andarwulan, 2023). This curriculum encourages the implementation of a scientific approach involving observation, experimentation, and data analysis, enabling students to develop stronger critical thinking skills (Festiyed et al., 2022).

In practice, science learning in schools is still dominated by conventional methods that do not actively engage students. Learning models that focus solely on delivering theoretical content through lectures and textbooks often fail to stimulate students' analytical thinking and critical reasoning toward scientific concepts (Ong'amo et al., 2017). The gap between theory and practice in science education remains a pressing challenge that needs to be addressed. Science learning should emphasize exploration and problem-solving to help students develop critical thinking skills (Toharudin, 2017). However, this approach is still rarely implemented optimally due to the limited availability of learning resources that support problem-based learning. The lack of innovative and interactive teaching materials tends to make students passive and less capable of connecting scientific concepts with real-world phenomena (Sun et al., 2022).

The impact of this gap results in students lacking well-developed critical thinking skills. In reality, many scientific phenomena in everyday life require critical problem-solving. Critical thinking skills are one of the essential competencies in Natural Sciences education, enabling students to systematically analyze, evaluate, and interpret information (Patricia et al., 2022). In science learning, critical thinking skills play a crucial role in developing students' ability to formulate scientific questions, design experiments, analyze data, and draw conclusions based on valid and logical evidence (Facione et al., 2016). The learning process needs to be adjusted to encourage students to connect scientific concepts with real-world phenomena, enabling them to improve critical thinking skills (Amin et al., 2020).

In the modern era, teachers play a crucial role in developing students' critical thinking skills through the selection of appropriate learning models and relevant resources (Kulolu & Karabekmez, 2022). Learning models such as Inquiry-Based Learning, Problem-Based Learning (PBL), and Project-Based Learning (PjBL) encourage students to explore problems, ask critical questions, and find solutions based on scientific evidence (Tari & Rosana, 2019). Additionally, the use of diverse learning methods, such as experiments, digital simulations, and contextual case studies, enriches the learning experience and enhances students' analytical and evaluative abilities (Kim et al., 2019). By implementing effective learning models, students can reflect on their thinking processes and connect scientific concepts to real-life situations, thereby optimizing the development of their critical thinking skills (Fajari, 2020).

One of the learning models proven effective in enhancing critical thinking skills is Problem-Based Learning (PBL) (Asyari et al., 2016). PBL is an instructional method that emphasizes real-world problem-solving as an initial step in building conceptual understanding and critical thinking skills (Yana & Yusrizal, 2022). In its implementation, PBL encourages students to analyze problems, identify relevant information, and develop evidence-based solutions through discussion and independent investigation (Groenewald et al., 2023). This process strengthens analytical, evaluative, and reflective thinking abilities, which are key aspects of critical thinking (Yew & Goh, 2016). Furthermore, PBL trains students to ask in-depth questions, evaluate arguments, and connect scientific concepts to real-world situations (Razak et al., 2022). However, the implementation of PBL in science learning still faces challenges, particularly due to the limited availability of learning resources that can systematically and structurally support this model.

In addition to problem-based learning models, integrating instruction with local wisdom or ethnoscience can be an effective strategy for enhancing critical thinking skills (Risdianto et al.,

2020). Ethnoscience connects scientific concepts with local culture, making learning more relevant and meaningful (Pieter & Risamasu, 2024). One example is the Reog Ponorogo performance, a traditional cultural heritage. In this performance, a dancer can lift a Dadak Merak, a decorative lion mask weighing 50 kg, using only their jaw strength. While this phenomenon is often perceived as mystical, it can actually be explained through the principles of force and motion in physics. However, the integration of culture in science education remains limited in schools. Many cultural phenomena can be analyzed through scientific concepts, yet students often miss the opportunity to understand science from a perspective closely related to their daily lives.

Addressing the gap between learning models and cultural integration can be achieved by developing relevant learning resources. Learning resources play a crucial role in fostering students' critical thinking skills, one of which is through the use of interactive and problem-based e-modules (Sriyati et al., 2021). E-modules provide structured content enriched with visualizations, simulations, and challenging problems, encouraging students to analyze, evaluate, and develop solutions to various issues (Mahmudah et al., 2022). With adaptive features, e-modules allow students to engage in self-directed learning at their own pace and according to their individual needs..

The integration of ethnoscience in learning aims to connect scientific concepts with local wisdom, making education more contextual and meaningful for students (Damayanti et al., 2017). One example is the Reog Ponorogo tradition, which is often perceived as involving mystical forces, particularly in the ability of dancers to lift the 50 kg Reog mask using only thir jaw strength (Wulansari & Admoko, 2021). However, this phenomenon can be scientifically explained through physics principles. By linking cultural phenomena with scientific theories, students can understand that science provides rational explanations for traditions without diminishing their cultural significance. The integration of ethnoscience in learning not only enhances critical thinking skills but also contributes to cultural preservation through an objective and scientific perspective (Wulandari et al., 2023).

The issues described align with the conditions observed at SMP N 2 Plung. Based on surveys and interviews with science teachers, it was found that teaching still relies on conventional methods, with textbooks as the primary learning resource, supplemented by commercially published student worksheets. However, the integration of local culture and the use of technology in learning have not been effectively implemented. As a result, student engagement remains low, and their critical thinking skills need further development. This is supported by survey results, which indicate that 87% of students reported a lack of interest in science learning, 81% found learning resources unappealing, 93% expressed a desire for new and engaging learning materials such as e-modules, and 97% stated that they were ready to use electronic learning resources.

An effort to address this issue is the development of an e-module that applies the Problem-Based Learning (PBL) model while integrating ethnoscience, specifically Reog Ponorogo. This integration not only enhances students' critical thinking skills but also serves as a means of preserving and understanding local cultural heritage. The incorporation of cultural elements in science learning is a new approach for both students and teachers, as cultural integration has not been fully utilized or examined from a scientific perspective in previous lessons. Through this e-module, students will develop an awareness that science and culture are not contradictory but rather complementary, enriching both their scientific understanding and cultural appreciation (Dewa & Astari, 2022). Furthermore, integrating the e-module with Problem-Based Learning can enhance critical thinking skills by presenting real-world scenarios that students must solve using scientific concepts (Adhelacahya et al., 2023).

Based on the background explanation above, this research aims to develop a Problem-Based Learning (PBL) e-module integrated with Reog Ponorogo ethnoscience to enhance the critical thinking skills of seventh-grade junior high school students. Through this e-module, students are expected to understand scientific concepts behind cultural phenomena or traditional beliefs, think critically about the scientific principles applied in Reog performances, rather than merely perceiving them as mystical occurrences. Additionally, students are expected to develop problem-solving skills by formulating scientifically grounded solutions to real-world challenges.

METHOD

This research is a Research and Development (R&D) research utilizing the 4D development model. The 4D model consists of four stages: define, design, development, and disseminate (Thiagarajan, 1974). However, this research is limited to the development stage, specifically focusing on a limited-scale trial. The limited-

scale trial was conducted with 10 seventh-grade students from SMP N 2 Plung and 2 science teachers.

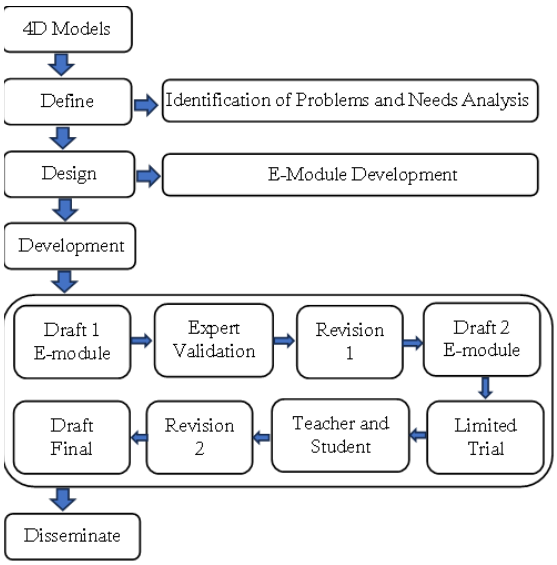

Figure 1. 4D models

The development of this media began with the definition stage, which aimed to identify and formulate learning needs. In this stage, an analysis was conducted to assess the feasibility of the media to be used and to map the learning materials. The results of this analysis served as a reference for the design process. The next stage was the design phase, which focused on developing the e-module. The main activities in this phase included designing the e-module layout and structuring the learning content, which was integrated into the digital media with supporting elements such as audio, video, articles, and relevant images. Subsequently, the development stage was carried out to produce a revised e-module based on expert feedback. The experts involved included media experts, content experts, and language experts. This stage also involved a limited-scale trial with prospective users, in which the readability of the e-module was tested with 10 students and 2 science teachers. Finally, the dissemination stage was conducted with seventh-grade students, using control and experimental groups to determine the effectiveness of the developed e-module in enhancing critical thinking skills.

The validity test was conducted to determine the feasibility value of the e-module. The validity test for feasibility was calculated using Aiken's formula.

$$V = \frac{s}{n(c-1)}$$

V = Aiken's Validity

s = The evaluator's score is subtracted by the lowest score in the category

n = Number of validators

c = The highest assessment score.

The feasibility assessment criteria for the e-module are determined based on Table 1.

Table 1. Feasibility Criteria of the E-Module Based on Aiken's Validity

Score	Criteria
V hitung > V tabel	Good
V hitung < V tabel	Bad
V hitung = V tabel	Revision

(Azwar, 2019)

The results of the expert validation analysis, including media, content, and language experts, were compared with the V table value of 0.78 to determine the validity of each item. An item is considered valid if its calculated V value exceeds the threshold, indicating it falls within the "good" category. This validation process ensures that the e-module meets the required quality standards for use in learning.

The limited-scale trial was conducted to determine the readability level of the developed e-module. The percentage of readability test results is calculated using the following formula:

$$\text{Percentage} = \frac{\text{Total assessment score}}{\text{Total score}} x\ 100\%$$

The criteria for the readability test results are determined based on Table 2.

Table 2. Criteria for e-module readability test

Precentage	Criteria
81-100	Excellent
61-80	Good
41-60	Enough
21-40	Less
<20	Very Less

(Arikunto, 2010)

The results of the e-module readability test analysis by students and science teachers were assessed using a percentage-based approach for aspects of content, product appearance, and ease of implementation or use. A learning material is categorized as excellent if it achieves a percentage above 80%, indicating that the content is easily understood by users. A high readability percentage also reflects the alignment of language, visual design, and the systematic presentation of the e-

module with the characteristics and comprehension level of the students.

RESULT AND DISCUSSION

Characteristics of the PBL-Based E-Module Integrated with Reog Ponorogo Ethnoscience

The Problem-Based Learning (PBL)-based e-module integrated with the ethnoscience of Reog Ponorogo was developed as an innovative learning resource that connects scientific concepts with local wisdom. The development of this e-module utilizes Heyzine and Canva to create an interactive and engaging design, complemented by images, videos, and learning activities that encourage active student participation in understanding the material. Additionally, this e-module is designed to be easily accessible on various smartphone brands without being constrained by low device specifications. With the Heyzine and Canva platforms, the e-module can function optimally as long as there is a stable internet connection. This ensures that all students, regardless of the type of device they use, can fully utilize the e-module in the learning process. The content in the e-module is designed to allow students to explore the scientific principles behind Reog Ponorogo. The PBL learning model implemented enables students to identify problems, formulate hypotheses, and seek solutions based on scientific evidence, thereby enhancing critical thinking skills (Amini et al., 2021).

The e-module developed in this research is designed based on the syntax of Problem-Based Learning (PBL) as the primary framework for the learning process. The PBL syntax consists of five main stages: problem orientation, organizing for learning, guiding investigation, developing and presenting results, and analyzing and evaluating problem solving (Ngadimin et al., 2021). Each stage in this syntax is systematically integrated into the e-module through problem-based scenarios, investigative activities, and interactive guidance that enable students to explore scientific concepts in depth. With this learning model, the e-module not only serves as a learning resource but also as a pedagogical tool that facilitates active and problem-based learning (Sujanem & Suwindra, 2023).

The syntax of Problem Based Learning (PBL) is closely related to the indicators of critical thinking skills. Each stage in PBL supports the development of specific aspects of critical thinking (Nia Anggraeni, 2023). The problem orientation stage plays a role in enhancing interpretation skills, where students identify and understand the given problem. In the organizing for learning stage, students develop analytical skills by breaking down relevant information and formulating problem-solving strategies. The guided investigation process in PBL encourages students to provide explanations for their findings based on the evidence obtained. Furthermore, the development and presentation stage trains students to evaluate the solutions they have developed, thereby sharpening their evaluation skills. In the final stage, analyzing and evaluating problem-solving, students are required to make logical inferences and develop self-regulation in assessing the effectiveness of the solutions produced. This relationship demonstrates that the implementation of PBL not only enhances conceptual understanding but also systematically strengthens students' critical thinking skills (Jatiningsih & Dewi, 2022).

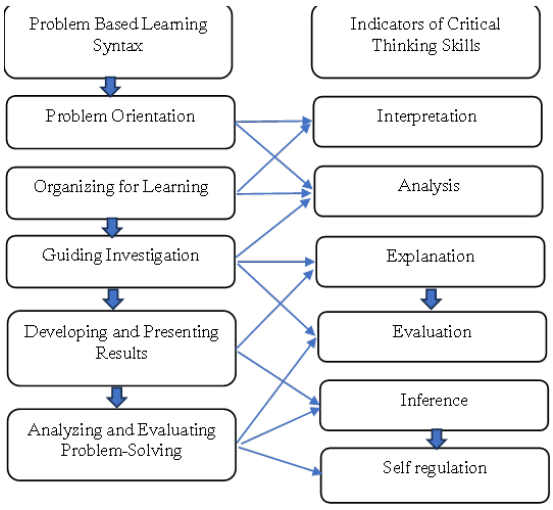

Figure 2. The Relationship Between PBL Syntax and Critical Thinking Skills Indicators

The syntax of Problem Based Learning (PBL) is closely related to the indicators of critical thinking skills. Each stage in PBL supports the development of specific aspects of critical thinking (Nia Anggraeni, 2023). The problem orientation stage plays a role in enhancing interpretation skills, where students identify and understand the given problem. In the organizing for learning stage, students develop analytical skills by breaking down relevant information and formulating problem-solving strategies. The guided investigation process in PBL encourages students to provide explanations for their findings based on the evidence obtained. Furthermore, the development and presentation stage trains students to evaluate the solutions they have developed, thereby sharpening their evaluation skills. In the final stage, analyzing and evaluating problem-solving,

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Based on the relationship between PBL syntax and critical thinking indicators, the developed e-module has the potential to enhance students' critical thinking skills (Sulhan et al., 2023). Through problem-based scenarios and exploratory activities, students are encouraged to actively engage in analytical and reflective thinking processes. The presentation of materials in the e-module, which is based on investigation and problem-solving, enables students to practice connecting scientific concepts with real-world phenomena, allowing them to evaluate problems systematically and rationally (Rahmat et al., 2020). Furthermore, interactive features in the e-module, such as simulations, virtual experiments, and self-reflection activities, support the reinforcement of self-regulation in critical thinking. Thus, this PBL-based e-module not only enriches students' learning experiences but also contributes significantly to the development of their critical thinking skills.

The developed e-module includes various learning components, such as systematically structured learning materials, Problem-Based Learning (PBL)-based worksheets to enhance critical thinking skills, learning evaluations to assess students' understanding, and explanations about Reog Ponorogo as an integration of ethnoscience in the learning process. Additionally, this e-module adopts green as the dominant color because green symbolizes balance, calmness, and freshness, which can enhance visual comfort for users.

The cover page of this e-module features an illustration of Reog Ponorogo as the main representation, emphasizing that the learning material integrates local cultural themes within an ethnoscience approach. The use of this visual element aims to capture students' attention while establishing a connection between scientific concepts and cultural phenomena familiar to their environment. Additionally, the introduction section includes a "Cultural Window" feature, which provides brief information on the history, philosophy, and key elements of Reog Ponorogo. This "Cultural Window" is designed to give students an initial understanding of the relationship between Reog culture and the scientific concepts to be studied, thereby fostering curiosity and enhancing learning motivation (Ratriana et al., 2021). This sense of curiosity, in turn, encourages students to develop critical thinking skills in understanding scientific concepts related to the subject matter.

Figure 3. Cover Page and Cultural Window

The presentation of learning materials in this e-module is designed to be interactive by incorporating images and videos to clarify the concepts being introduced. Visualizations in the form of images help students understand structures and phenomena more concretely, while videos allow them to observe processes or events dynamically. The integration of these media aims to enhance students' active engagement in learning, strengthen conceptual understanding, and accommodate diverse learning styles. At the beginning of the lesson, students are presented with images and questions related to issues in Reog performances and are encouraged to think critically about the causes of these issues and their impact on the performance. The e-module also includes illustrative content in the form of images and videos, which help make abstract concepts more tangible. Additionally, the inclusion of videos allows students to repeatedly observe events in Reog performances, facilitating the analysis process and improving their critical thinking skills.

Figure 4. Learning Material Page Display

This e-module is equipped with worksheets designed based on the Problem-Based Learning (PBL) syntax to develop critical thinking skills. These worksheets are presented interactively using Liveworksheets, making it easier for students to complete their tasks. With easy access, students can engage with the e-module anytime and anywhere, ensuring flexibility and practicality in the learning process. Additionally, the integration of interactive features enhances student engagement and motivation, creating a more dynamic and immersive learning experience. The systematic and engaging presentation of the material is expected to help students better understand concepts and support the effectiveness of problem-based learning.

Figure 5. Student Worksheet Page

In the first subchapter, the worksheet is designed to encourage discussion on the concept of motion in Reog Ponorogo performances. An article and a video are presented, explaining the belief that fast movements in Reog dancing symbolize agility and dexterity, while slow movements represent the pride and authority of a lion king. In this activity, students conduct a simulation experiment by lifting an object that symbolizes the Reog mask. They are asked to move along a specific path while measuring distance, speed, and average velocity during the simulation. Afterward, students analyze the purpose behind the dancer's movements, connecting them with scientific principles and community-based knowledge related to the issue. Through this contextual discussion and analysis, students not only gain a theoretical understanding of physics concepts but also relate them to real-life phenomena in local culture. This approach enhances their critical thinking skills and scientific problem-solving abilities (Patricia et al., 2022).

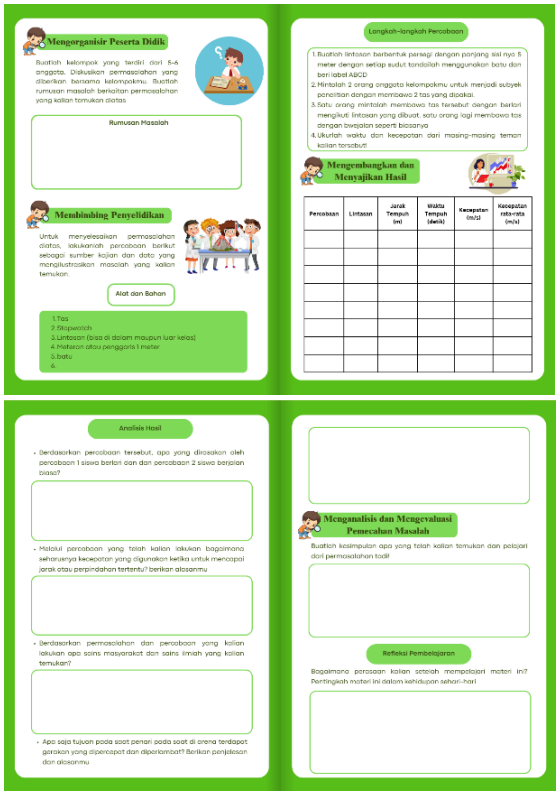

Figure 6. Simulation Instructions and Student Result Analysis on Motion Material Worksheet

In the second subchapter, the worksheet is designed to encourage discussion on the concept of force in Reog Ponorogo performances. An article and a video are presented, explaining the belief that dancers can lift the 50 kg Reog mask, sometimes even with a person sitting on top, due to mystical forces making it appear effortless. Students are required to analyze this phenomenon and then conduct an experiment by lifting a chair as a simulation to determine whether there is a difference in load when carrying one chair versus two chairs. They are then asked to walk on both smooth and rough surfaces and observe their experience when stopping suddenly or moving slowly, similar to a Reog dancer. Students record their observations and analyze the data collected, relating it to the applied forces, the consequences if force were not present, as well as the scientific and community-based explanations of the issue. By conducting hands-on experiments and encountering real-world phenomena, students can enhance their critical thinking skills through analysis, evaluation, and logical conclusions based on empirical evidence.

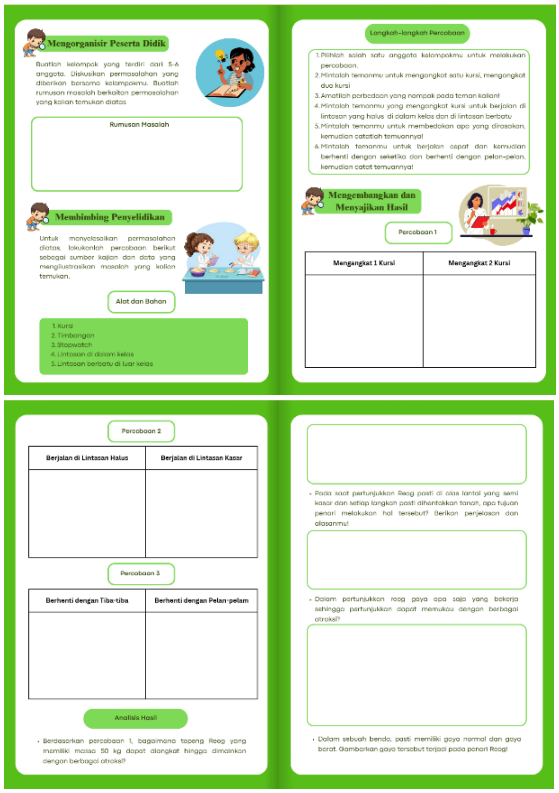

Figure 7. Simulation Instructions and Student Result Analysis on Force Material Worksheet

At the end of lesson, an interactive quiz using Quizizz is presented as a reflection tool for students to assess their understanding of the material learned. The gamification features in Quizizz, such as instant scoring, competitive elements, and real-time feedback, enhance students' motivation and active engagement in the evaluation process. Interactive quiz allows students to learn enjoyable manner without feeling burdened when assessing their comprehension. Thus, the use of Quizizz as a reflection tool at the end of the lesson not only helps measure the effectiveness of learning but also encourages students to independently reflect on their understanding and identify areas that need further improvement.

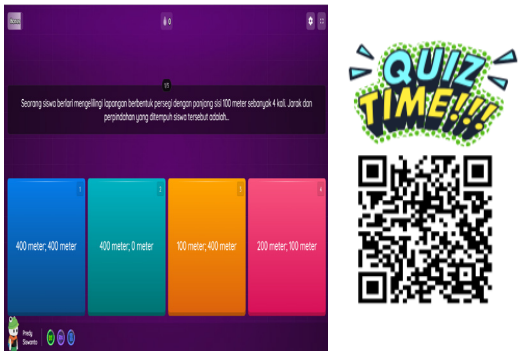

Figure 8. Quizizz Page Display

Validity of the PBL-Based E-Module Integrated with Reog Ponorogo Ethnoscience

The results indicate the feasibility score of the PBL-based e-module integrated with Reog Ponorogo ethnoscience, as assessed by media, material, and language experts, analyzed using Aiken's V validity. Validity refers to the degree of accuracy and precision of an instrument in measuring what it is intended to measure. The expert assessment results analyzed using Aiken's V formula are presented in Table 3.

Table 3. Media Expert Validation Results

Aspects	Item Number	V	Description
E-Module Cover Design	1	0.91	Valid
	2	1	Valid
	3	0.95	Valid
	4	0.91	Valid
	5	0.91	Valid
	6	0.91	Valid
	7	0.91	Valid
	8	0.95	Valid
E-Module Initial Page Design	9	0.95	Valid
	10	0.91	Valid
	11	0.91	Valid
	12	0.91	Valid
	13	0.91	Valid
	14	0.91	Valid
	15	0.91	Valid
E-Module Content	16	0.91	Valid
	17	0.91	Valid
Design	18	1	Valid
	19	0.95	Valid
	20	0.91	Valid
	21	0.91	Valid
	22	0.95	Valid
	23	0.91	Valid
	24	0.91	Valid
	25	0.95	Valid
	26	0.91	Valid
	27	0.95	Valid
	28	0.95	Valid
	29	0.95	Valid
	30	0.91	Valid

Based on Table 3, the validation results from six media experts on 30 instrument items

indicate that all items are declared valid, as the calculated V value is greater than the table V value (0.78). This suggests that the instrument used meets the eligibility standards as a measurement tool for assessing the quality of the e-module. Media expert validation was conducted to ensure that the visual and technical aspects of the e-module align with effective instructional design principles and can support students' comprehension (Rahmayanti & Andayani, 2023).

The aspects validated by media experts include the cover design, page design, and content design of the e-module, all of which play a crucial role in enhancing student engagement in learning. The cover design is crafted to reflect the ethno-science theme of Reog Ponorogo, capturing students' attention and establishing a cultural connection to the science material. The e-module's page design considers layout, color selection, and readability to support reading comfort and facilitate navigation in digital-based learning. The content design focuses on presenting materials through a combination of text, images, and interactive videos, ensuring that the e-module not only meets aesthetic and technical standards but also serves as an effective learning resource that integrates scientific concepts with the local wisdom of Reog Ponorogo.

Table 4. Subject Matter Expert Validation

Aspect	Item	V	Description
Material Suitability	1	0.91	Valid
	2	0.91	Valid
	3	0.875	Valid
Material Accuracy	4	0.875	Valid
	5	0.83	Valid
	6	0.875	Valid
	7	0.875	Valid
	8	0.91	Valid
Learning Material Support	9	0.875	Valid
	10	0.91	Valid
	11	1	Valid
	12	0.91	Valid
	13	0.83	Valid
Material Up-to-dateness	14	0.875	Valid
	15	1	Valid
	16	0.83	Valid
	17	0.91	Valid

Based on Table 4, the validation results by six subject matter experts on 17 instrument items indicate that all items are deemed valid, as the calculated V value is greater than the table V value (0.78). This demonstrates that material developed in the e-module meets academic feasibility standards and can be used as a valid learning resource. The validation by subject matter experts was conducted to ensure that the content of the e-module aligns with learning objectives and effectively supports students' understanding.

The aspects assessed in the subject matter expert validation include material suitability, material accuracy, learning material support, and material up-to-dateness. Material suitability refers to the alignment of the e-module content with the learning outcomes set in the curriculum, ensuring that the presented content is relevant to students' needs. Material accuracy pertains to the correctness of concepts and scientific principles used, in accordance with well-established theories. Learning material support, such as images, videos, and contextual examples based on the ethnoscience of Reog Ponorogo, aims to facilitate students' understanding by connecting scientific concepts with cultural phenomena. Meanwhile, material up-to-dateness ensures that the information presented in the e-module is updated based on the latest scientific developments, in line with the constructivist principle that emphasizes experience-based and up-to-date knowledge learning (Sunarti, 2024). Thus, the validation by subject matter experts ensures that the e-module not only meets academic standards but also serves as an effective and innovative learning medium.

Table 5. Results of Language Expert Validation

Aspect	Item	V	Description
Concise	1	0.95	Valid
	2	0.91	Valid
Interactive	3	0.91	Valid
	4	0.875	Valid
	5	0.91	Valid
Appropriate for Student Level	6	0.91	Valid
	7	0.91	Valid
Language Rule Compliance	8	0.875	Valid
	9	0.91	Valid

Based on Table 5, the validation results by six language experts on nine instrument items indicate that all items are deemed valid, as the calculated V value is greater than the table V value (0.78). These results demonstrate that the linguistic aspects of the e-module meet the necessary

criteria to optimally support students' understanding. This validation ensures that the language used in the e-module conveys information clearly, effectively, and appropriately according to the characteristics of the students.

The validation by language experts includes conciseness, interactivity, appropriateness for student level, and language rule compliance. This aligns with Vygotsky's cognitive theory on the Zone of Proximal Development (ZPD), which emphasizes that the language used in learning materials should bridge students' understanding from their initial level to a more advanced level (Wardani et al., 2023). Additionally, the use of interactive language aligns with Piaget's constructivist principles, which emphasize that learners actively construct knowledge through language that is easy to understand (Agustyaningrum & Pradanti, 2022). The e-module not only ensures clarity in material delivery but also supports students' critical thinking and independent learning processes in alignment with the PBL model.

The validation results of e-module demonstrate that this learning medium has met the feasibility standards before being implemented in the learning process. Validation is conducted to ensure that e-module is suitable for use in terms of content, language, and media, thereby supporting learning effectiveness. The development of teaching materials must go through evaluation and revision stages to ensure quality before implementation. Additionally, alignment between learning objectives, methods, and assessments is crucial in creating meaningful learning experiences.

A limited-scale trial was conducted with 10 students and 2 science teachers to evaluate the readability of the developed e-module. This activity aimed to ensure the language, layout, and presentation of material in the e-module were easily understood by students. The trial results served as a basis for improvements before e-module was implemented on a larger scale, ensuring that the presented material was clearer, more engaging, and aligned with learning needs. The results of teachers' assessment are presented in Table 6.

Table 6. Science Teachers' Readability Test

Assessment Aspect	Score	Category
Content	92.5	Excellent
Product Appearance	91.25	Excellent
Implementation	88	Excellent
Average	90.5	Excellent

Based on Table 6, the readability test results from science teachers indicate that the e-module received an average score of 90.5, which falls into the "excellent" category. These results suggest that the e-module has met the necessary readability standards to effectively support the learning process. The readability test encompasses three main aspects: content, product appearance, and implementation. The content aspect is evaluated based on the clarity of concept delivery and alignment with the curriculum, the product appearance aspect includes visual design and ease of navigation, while the implementation aspect assesses the ease of use of the e-module in learning activities.

Table 7. Results of Student Readability Test

Assessment Aspect	Score	Category
Content	88	Excellent
Product Appearance	79	Good
Implementation	90	Excellent
Average	85.6	Excellent

Table 7 shows that the readability test results from students obtained an average score of 87.3, which falls into the "excellent" category. These results indicate that the e-module has a high level of readability, making it easy for students to understand and use. Additionally, the visual aspect was also rated as attractive, contributing to increased student learning motivation. The readability test confirms that the developed e-module meets feasibility standards as a digital teaching material that effectively and interactively supports the learning process.

Based on the readability test results conducted by teachers and students, the development of the Problem-Based Learning (PBL)-based e-module integrated with the ethnoscience of Reog Ponorogo has shown a high level of readability. This indicates that the e-module is easy to use, visually appealing, and aligned with the characteristics of students. Good readability serves as an indicator that the e-module meets the principles of effective instructional design, where learning materials should be structured clearly, systematically, and engagingly to enhance students' understanding. The appropriate combination of visual elements and text can further improve student engagement and learning effectiveness. With these results, the e-module can be implemented in a broader trial to assess its effectiveness in enhancing critical thinking skills.

This study has several limitations, including a limited research scope and the absence of empirical testing on the effectiveness of the e-module in enhancing critical thinking skills through

trials in an experimental class with a control class. Future researchers are expected to use findings of this study as a reference for developing e-modules by integrating more adaptive and user-friendly features, making them easier to use in learning and suitable for long-term implementation.

CONCLUSION

Based on data analysis, it can be concluded that the development of a PBL-based e-module integrated with ethnoscience combines local cultural elements into learning materials that are scientifically examined. Validation by media, content, and language experts indicates that each item is considered valid, as the calculated V value is greater than the table V value (0.78). Additionally, the readability test results show that the e-module received an average score of 90.5 from teachers and 87.3 from students, both classified as excellent. With these results, the developed e-module has met feasibility standards as a digital teaching material and can be tested on a larger scale to measure its effectiveness in enhancing students' critical thinking skills.

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